tation. And further, that the Member of each Committee to retire from the Council be that one who has given the least number of attendances during the year."

The amendment having been negatived, the original Recommendations of the Council were put and carried.

In the absence of the author, the Rev. T. R. Robinson, D. D., Sir Robert Kane read a second notice on the Luminous Phenomena produced by the discharge of Ruhmkorff's Induction Apparatus in vacuo:—

"In the Proceedings of the Academy, January, 1856, I have given an account of some observations respecting the appearances produced by the discharge of induction currents through an exhausted receiver; especially the division of the luminous stream into a number of spherical shells, whose centre is the point from which the positive discharge issues, and the influence which the presence of gaseous or vaporous matter has on the production of those rays which have the power of exciting fluorescence. Since that time I have pursued the subject at such few moments of leisure as I could find; and I hope the facts which I have observed may not be unworthy of the Academy's notice. If it seem that I detail them too minutely, it must be remembered, that as long as we are ignorant of the cause of a phenomenon, it is impossible to decide as to the importance and significance of any of its features.

"Nothing satisfactory has yet been ascertained as to the cause of the stratification of the light. Mr. Grove, in a communication to the British Association at Cheltenham (which I know only from a very brief notice in the 'Athenæum'), appears to think that it arises from some vibration in the metal of the contact-breaker, which produces a fluctuation in the inducing current. He finds that it is not always visible in the light caused by a single discharge, and that it is influ-

enced by the nature of the metals between which the interruption spark occurs. The opinion of such a man is of great authority; yet it is not easy to see how this can produce such an effect; and the following observations appear to show that other circumstances must also be concerned in it:—

"1. I tried the effect of frictional electricity from a machine of two 18-inch plates in powerful action. The lower electrode was an inch ball, screwed into the opening of the pump-plate (which is of glass): the upper was a point, 7 inches distant. The receiver was filled with dry hydrogen. On exhausting to 1$^{\mathrm{i}}$·0, the light appeared filling the receiver, and did not pass in a central stream till 0$^{\mathrm{i}}$·09. At 0$^{\mathrm{i}}$·06 a few faint bands were seen near the ball, which, with its stem, had a faint envelope surrounded by a brighter one, but no difference of colour. The light was greenish, producing no fluorescence, and very much fainter than that produced by Ruhmkorff. Nothing was gained by including a jar of one-third foot coating discharging at 0$^{\mathrm{i}}$·10. With the air vacuum 0$^{\mathrm{i}}$·15, the light was violet, much fluorescence, and the bands less distinct.*

"2. An 'electric egg,' 8$^{\mathrm{i}}$·5 high, and 6$^{\mathrm{i}}$ diameter, was filled with hydrogen.† The balls of its wires, 0$^{\mathrm{i}}$·25 diameter, were set 6$^{\mathrm{i}}$ apart, and it was exhausted to 0$^{\mathrm{i}}$·17 (the pump not acting well then). The Ruhmkorff was excited by four Groves giving in air a spark 0$^{\mathrm{i}}$·52. When the current

* Within the last few days I had an opportunity of reading the last two years of Poggendorff's "Annalen." In the 7th Number of this year I find an important observation of Herr Van Willigen. He saw dark bands in the discharge of the Leyden jar through a vacuum of 0$^{\mathrm{i}}$·12 (containing vapour of oil of bergamot), when a wet string is included in the circuit. Hence, he, and Poggendorff subsequently, infer that they require a certain retardation of the discharge. It seems rather to confirm Mr. Grove's view of a certain undulation in the current being necessary.

† The gases were always dried by being slowly passed through a capillary tube immersed 6$^{\mathrm{i}}$ in sulphuric acid.

through the primary coil was reduced to 0·52 of my unit, the machine worked, though feebly, and the light was pale and cylindrical, *without a trace of stratification anywhere*. As the current was increased, the outline of the light became elliptic, but no bands were visible *till the current* = 1·51, and then only a few at the positive ball. With the full current = 3·60, they were brought out in perfect development. It deserves to be remarked, that when the lower ball is positive, the central light almost touches the other ball; but when the current is reversed, there is the usual dark interval at the negative. The glass of this egg is thick, and very fluorescent, and absorbs completely the few rays of high refrangibility which are produced in the hydrogen vacuum, so that none of the tests are affected outside.

"3. Occasionally I use a Smee's battery of six cells, with plates the same size as my Groves. It is, however, very inferior to Grove both in power and constancy, the *six* not giving as strong a current with the Ruhmkorff as *one* of the others. Connecting it, when excited by them with a receiver in which was a hydrogen vacuum = 0^{i}·08, the meniscoid strata were *at first* very distinct, but faded away in a few seconds. The lower electrode was a point, the other an inch ball, in which there was a hole about 45° from its stem. Out of this darted a curious funnel of pink flame, passing through the interior envelope and the dark shell which surrounded it, and spreading itself into the exterior brighter one. When only the exterior terminal of the Ruhmkorff is connected with the upper ball, the light is faint and without stratification: the ball has the two envelopes with the dark interval, which cease at its equator, and this whether it be positive or negative.

"4. In strong contrast to this is the powerful development of stratification, when there is passed through the hydrogen vacuum 0^{i}·07 the current of two Ruhmkorffs, excited by a triple Grove, and, as Foucault proposes, connected by their interior terminals and their exterior terminals, oppositely

electric. This arrangement gave in air dense sparks $0^{i}\cdot 8$ long. The appearances were very fine. A few of the menisci near the positive ball were $0^{i}\cdot 2$ broad, and did not fine away at the edge as much as usual.

"5. Wishing to prevent the diffusion of the luminous stream, I screwed on the point a disc of gutta percha, of such size as to touch the glass. With air vacuum $0^{i}\cdot 05$, and Smee, when the point was positive, a few menisci were occasionally seen near it; but when a hand was brought near the receiver, they *were much more strongly developed towards it.* When a Leyden jar (each coating about a foot) was connected with the terminals, the stratification was well seen in each direction of the current. With the two Ruhmkorffs combined, and three Groves in series, the effect was magnificent: all the distance from the point to an inch from the ball was covered with bright yellowish-green menisci: the envelopes of the ball were broad, and the cone of pink light from the hole already mentioned dazzling. Reversing the current, the outer envelope of the point sent several bright streams round the gutta percha, which partly fused it. With air vacuum $0^{i}\cdot 10$ the appearances were less intense; the stratification reached only half way, and the envelopes of the negative ball were not one-fourth of their previous bulk.

"6. The destruction of the gutta percha made me replace it by a disc of plate glass 3^{i} diameter, with a small hole drilled in the centre. To this is cemented a tube of gutta percha, which slips on a wire screwed in the pump-plate, whose point projects $0^{i}\cdot 1$ above the glass. This arrangement gives beautiful results. With air vacuum $0^{i}\cdot 07$, and Smee, when the point is positive, on first passing the current the menisci appeared at the dark space near the ball, then in a few seconds travelled *down* the column of light, like waves from a stone thrown into water, and when they reached the point, disappeared. If the ball was positive, the column of light had an elliptic envelope reaching to the dark part. Be-

low this the point had its envelopes and the blue light, above which was a convex haze reaching to the edge of the glass, and streaming round it in a pink cone to the brass nut which secures the glass plate. With two Groves the strata were permanent, but cannot be called menisci, as in *this arrangement* the decrease of thickness at the edge scarcely occurred.

"7. This, with hydrogen vacuum $0^{i}\cdot05$ and two Groves, gave far less light than in the air vacuum. There was no fluorescence with sulphate of quinine, but a little with platino-cyanide of potassium.* With the ball positive, the spherical shells were well formed, but only through half the column of light: below that was luminous haze down to the dark interval near the point. When the point was positive, the shells *were perfect hemispheres, with the glass disc as their diameter, and reaching to its edge:* above that they were lesser segments, which did not extend to the glass of the receiver.

"8. Substituting for the ball a glass disc similar to that below, and depressing the points $0^{i}\cdot05$ *below the surface* of the glass, air vacuum $0^{i}\cdot08$, four Groves, this seemed to interfere with the production of the strata, which were scarcely perceptible, and the stream of light, though intense, was narrow. Making the lower point to project $0^{i}\cdot10$, as before, they were much plainer when it was positive, but scarcely to be seen when it was negative. Replacing the ball, they were, as usual, spreading out into the faint envelope. When the induction circuit was not continuous, but completed by dropping sparks on the bind-screw of the pump-plate, or on a globule of mercury placed there, no change was produced in their appearance. When the contact breaker was surrounded by alcohol (which reduced the spark in air from $0^{i}\cdot42$ to $0^{i}\cdot34$) there was no alteration, except what arose from the diminished current.

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* For this I am indebted to G. G. Stokes, Esq. It is the most sensitive test of fluorescent rays that I know.

"9. Supposing the vicinity of the glass of the receiver to the luminous stream might have some effect, I used a larger one, 6^{i} internal diameter, and allowing 6^{i} from the ball to the glass disc. With Smee and air vacuum $0^{i}{\cdot}04$, the hemispheres covered the disc, about 40 to the inch, in the stream above still closer; but besides these, others were occasionally seen, broad, hazy, and *not curved*, which seemed to move rapidly, if the eye was suddenly depressed. These are, probably, an optical deception.

"10. With hydrogen vacuum and Smee, at $0^{i}{\cdot}70$, the ball positive, the stream was bright, and covered with fine black bands: then it broke into a faint broad one, with lateral brushes to the glass, in which no bands were visible. With the point positive, the stream was bright, $0^{i}{\cdot}4$ broad, reaching $0^{i}{\cdot}5$ from the ball, and all covered with fine sharp bands. Round it was a faint envelope, into which the bands occasionally darted out, *but only every second or third one*. At $0^{i}{\cdot}6$ the bands became hemispheres, covering the whole glass disc, full twice as broad as the first set, but worse defined, misty, and the intervals not absolutely dark. The mass of light ended in a cone, whose point was about $1^{i}{\cdot}5$ from the ball.

"11. I was indebted to Mr. Mallet for the use of a large Ruhmkorff: it was the same diameter as mine, 4^{i}, but longer, in the ratio of 11·5 to 7. It did not give a longer spark in air, but a far denser one. Excited by four Groves, hydrogen vacuum at $4^{i}{\cdot}2$, the discharge passed in faint ramifications. At $1^{i}{\cdot}70$ it was a bright ribbon, $0^{i}{\cdot}25$ broad, between green and lilac, covered with faint bands, which attained their maximum of distinctness at $0^{i}{\cdot}70$. At $0^{i}{\cdot}14$ the appearances were the normal ones of this vacuum, but finer than I had ever seen them. When the ball was positive, the shells wrapped round it, and were a little flattened below it on each side of the axis.

"12. Admitting air and exhausting, the discharge passed at $2^{i}{\cdot}70$, in bluish branches, filling the receiver. At $1^{i}{\cdot}52$ it

passed in a single red stream, but without bands. At $0^{i}\cdot04$ the spherical strata and the rotation were admirably developed. It was especially beautiful when the ball was positive. The blue hemisphere on the point was surrounded by a dark shell, whose projection on the disc looked like a black ring. Round this was a pink one, which folded round the disc, and formed the cone already described. In this also were bands, which, at the part which bent round the edge, looked like fiery spikes. I have never seen stratification in the blue light.

"13. Vacuum of coal gas, which had been passed through sulphuric acid, $0^{i}\cdot03$, Smee, point positive; the light was bright green; pink stars on the point; lilac shell on ball. The strata were very fine, but flattened on each side of the axis; there also were broad secondary bands, as in (9), which sank down like waves. The ball, when positive, was wrapped in a luminous haze, and covered with green stars; others were on the point. After a few seconds the strata became faint. There was barely a trace of fluorescence with the platino-cyanide.

"14. Air vacuum $0^{i}\cdot025$, Smee. With the point positive the strata were very distinct at first, but soon faded: there were also the broad shadowy bands which *this time rose.* Stopping the action of the battery for 60^{s}, the strata reappeared: once or twice the light reached the ball, *without any intervening dark space.* When the point was negative, the glass disc was covered with circular rings, which continued round its edge and down the cone, as in (11) and (12), with higher electric power, but less exhaustion.

"15. With hydrogen vacuum $0^{i}\cdot12$, and two Groves, the electrodes being a half-inch ball screwed into the pump-plate, and a brass plate closing the top of a tall receiver, with a distance of 17^{i} between them, there was scarcely any stratification. This was also the case with the air vacuum; but when the distance was only $5^{i}\cdot5$, they had their usual character, and were very distinct.

"These experiments indicate three things, as exerting a potent influence on this peculiar stratification of the light, the chemical character of the medium, its density, and the intensity of the induced current which is discharged through it. These three may be reduced to one, namely, the quantity of electricity which is transmitted in a given instance; and which depends on the conducting power of the circuit and the electro-motive force. The superiority of hydrogen and coal gas over common air arises from their being better conductors; and as any gas becomes a better conductor by rarefaction, this explains why, through the whole series, the phenomena are most distinct when the vacuum is best.* Indeed, for each gas there seems to be a limit of density above which stratification does not occur. Thus, for hydrogen, the bands were not seen (10) till its pressure $=0^{i}{\cdot}70$, and in another instance (11) where the electric tension was higher, till $1^{i}{\cdot}70$. In air I have never seen them when its density was more than $0^{i}.30$. This limit will be highest for the best conductors; but it is seen by comparing (14) with (7) that inferior conducting power may be more than compensated by higher exhaustion.

"The proofs of the influence of electric tension are still more numerous. In (3), (6), (13), and (14), where Smee's battery was used, the strata, though distinct at first, faded away in a few seconds, reappearing when the circuit was broken for a short period. The power of this battery, like that of other single fluid ones, declines rapidly when the circuit has small resistance, and recovers when that is broken; and in these two states the induction spark in air was $0^{i}{\cdot}20$ and $0^{i}{\cdot}05$: this decline caused the disappearance. The trifling effect of frictional electricity (1), as compared to that of the

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* As the rarefaction proceeds, the intensity of the spark at the contact breaker decreases; and so also we should suppose the vibration there; yet the stratification becomes more decided. This seems against Mr. Grove's hypothesis.

induction machine, depends obviously on the inferiority of quantity; and the difference (15) when the distances of the electrodes are 17^{i} and $5^{i}{\cdot}5$ must be referred to the same cause. In (5) the hand acts by facilitating the passage of the electricity, and in (6) and (7) the stratification increases in distinctness with the increase of the battery current passed through the primary coil. In (8) and (11) the battery power is the same, but the latter has a more powerful induction coil, and its effects far surpass the other. Still more striking is the effect of combining two machines, (4) and (5), where the power of quantity over this phenomenon is manifest; and that of connecting a Leyden jar with the terminals of the induction coil, which decidedly weakens the spark at the contact breaker, is also considerable. And it appears from (2), not only that it increases with the current, but that a certain amount is necessary to its production, less, as might be expected, for hydrogen than air. That the electrodes of the induction discharge exercise a decided influence on this phenomenon is shown by (7) and (8). In the latter the quantity of electricity which passed was probably less, but in the other the appearance of the hemispheric shells covering the whole disc is very striking, and suggests the idea of two systems of waves emanating from the positive point. It seems desirable to study the effect of points of different substances; of the various velocities of the contact breaker; and of very intense induction,* and I hope soon to be able to do it.

"In my former paper I expressed an opinion that oxygen and nitrogen are the only gases in which the electric discharge produces those rays which cause fluorescence, and promised to examine others besides those mentioned there, by means of

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* A very great increase of this machine's power has recently been made by Ruhmkorff himself, by Stöhrer of Leipzig, and still more by Heerder of Plymouth. We are, probably, far from the limit, though it has given sparks exceeding three inches.

a peculiar apparatus which I described. This I have done, though not as far as I wish. The plan of closing the bell which is mentioned there, failed on trial; and I used as a valve a disc of iron, having in its centre a convex projection fitting the hole, round which is a thin washer of vulcanized caoutchouc. This is kept tight by a screw, the head of which can be caught by a hook on the sliding rod of the receiver, and the bell may thus be raised (for I found its flotation uncertain). The bell holds 19 inches, and the little jar which I use to transfer gas into it holds $\frac{1}{67}$, so that the density when it is in its normal position = $\frac{1}{1277}$. At first some air adheres obstinately to the bell, and some escapes from the pores of the iron core, in spite of varnish; but after repeating the process three or four times, no trace of it appears. The distance between the iron disc, and the surface of mercury which is the lower electrode = $5^{i}\cdot 5$.

"16. When no gas is introduced, I presume the vacuum contains nothing but mercurial vapour; with Smee the disc was covered with a film of pink; then there were broad, bright, green, spherical shells extending across the bell to a radius of $1^{i}\cdot 5$. From them a faint haze spread down in a cone, so as actually, or almost, to meet a similar cone rising from a stratum of bright, blue light (in which no stratification was visible), floating on the mercury. The whole is so like the appearance in hydrogen, that I feel almost sure the latter is a *gaseous metal.* There was no fluorescence; but as I had learned from (2) that it might be concealed by the absorption of the glass, I lately repeated this experiment, placing on the *inside* of the bell's dome a spot of sulphate of quinine, and one of platino-cyanide of potassium. When the disc was positive, so that these tests were enveloped in the green menisci, they showed no fluorescence whatever; when it was negative, and they were exposed to the blue light, the platino-cyanide showed the faintest possible trace; the other none. This vacuum is a worse conductor than the external air one, $0^{i}\cdot 15$.

"17. Introducing the jar with air, which gives the vacuum

$0^{i}\cdot02$, the light is of the usual violet colour, the fluorescence strong, and the spheric stratification the most distinct which I had seen with air. When the disc is positive, the form of the light is as in the preceding; when negative, there is a sheet of pink light on the mercury, and the bell is full of dazzling blue, as fluorescent as the other.

"18. Vapour of carburet of sulphur: a few drops are poured into the transfer jar, which is then filled with mercury, so as to displace all except the film which adheres to the jar. This, when the jar rises out of the hole, is vaporized: with water the quantity which thus adheres = $\frac{1}{15}$ grain. In this case the tension of the vapour was about $0^{i}\cdot15$, as estimated by the height of mercury in the bell, compared with the gauge. The light was bright yellow green, the strata superb, but no exterior fluorescence. In a short time it was decomposed, the bell being coated with sulphur, and the mercury with a red film, probably cinnabar.

"19. Vapour of chloroform seems to conduct badly: the light is greenish, but with many branches; no fluorescence, and strata indistinct. The vapour was probably too dense.

"20. A bit of phosphorus, carefully dried, was passed up into the transfer jar. At first the appearance was as in (16), but as the phosphorus evaporated, one of the hemisphere shells about $0^{i}\cdot5$ diameter became brilliant gold colour, and stretched itself up and down, while the others changed colour also, becoming bluish-white. It then shrunk into a film, coating the disc, but retaining its peculiar splendour. Below them, for a third of the whole, there was a dark space, and orange light on the mercury; no fluorescence with quinine, and very little with platino-cyanide. Reversing current, the disc is orange, and the bell full of white light, which soon separates from the glass, forming a cone. Much phosphuret of mercury is formed. This is the most beautiful *spectacle* of all which I have seen.

"21. Sulphurous acid gas: I had some trouble in filling these miniature jars ($0^{i}\cdot1$ diameter), but did so by means ob-

vious to every practical chemist. Four were always filled, and tried in succession. The light in this was a rich lilac, with a bright central portion. Platino-cyanide looked dull white; but uran glass and quinine drawings scarcely showed anything.

"22. Iodine acted so rapidly on the mercury, and obscured the glass, that I could observe nothing.

"23. Hydrochloric acid was so bad a conductor, that I had difficulty in preventing the discharge from passing outside the bell. The light was yellowish-gray; no strata, and less fluorescence than hydrogen.

"24. Cyanogen was not like any other I had seen: the light is a deep lilac, no blue at the negative electrode, but only a deeper tint of the general hue. It *is very fluorescent*, not perhaps quite so much as air, and the discharge is less luminous. After some time a change takes place, for the light becomes greenish, and the strata are more sharp; perhaps cyanide of mercury is formed.

"25. Vapour of naphtha gave nothing peculiar; the light was livid blue, and scarcely a trace of fluorescence.

"26. Vapour of alcohol: the light was brilliant beryl-green, and orange at the disc when positive; bare trace of fluorescence with the platino-cyanide.

"27. Fluoride of silicium gave an indefinite colour between lilac and green, reaching nearly to the mercury, where it was a strong brownish-yellow. The disc, though iron and positive, was covered with stars of green light, and there was only the faintest fluorescence with platino-cyanide.

"28. Dentoxide of nitrogen differed in nothing from air, except that when the disc was negative the combustion was more vivid, and sparks of burning iron were thrown off.

"29. Ammonia gave a pale livid light, with *scarce a trace of fluorescence*, though the strata were highly developed.

"30. Vapour of water is so bad a conductor, that the discharge would not pass till the density in the receiver was

$3^{i}{\cdot}5$, which reduced the striking distance to 2^{i}. The light was *greenish*, faint, and fluorescence almost insensible.

"31. Concentrated acetic acid showed nothing worth notice; the light was livid, and fluorescence very faint.

"32. A fragment of camphor was fixed by pressure on the disc. The light was green, like that of alcohol; when the disc was positive, it was covered with intense emerald stars, and the mercury with bluish-green light, brighter than the rest. This was still brighter at the disc when negative, and red sparks flew from it. No fluorescence.

"33. This was again tried in the air vacuum $0^{i}{\cdot}25$, but with four double Groves. The light was light green, but the stream narrow, and the strata were well defined. Red sparks flew from the negative electrode; quinine drawings were not visible outside, but one attached to the inside of the glass was seen faintly. This was probably caused by the residual air.

"It follows from these facts, that though my original conclusion, that the fluorescent rays can be produced only in oxygen and nitrogen, is not rigorously true; yet that in this respect they very far predominate over the others. It appears from (27) that they do not lose this quality in combination; and from (23) that nitrogen is not deprived of it by carbon, though it is (28) by hydrogen, which seems eminently anti-fluorescent. It, sulphur, and carbon, seem entirely to destroy this power in oxygen; and probably the case is the same with all other highly electro-positive substances. Equally deserving of notice is the power of developing green light which seems to belong to the compounds of carbon. There remains a wide field for inquiry on these points, especially with respect to the various ethers and bodies of the same family, and also to the remaining electro-negatives, on which I hope soon to enter, with the advantage of having in some degree ascertained the difficulties which are to be encountered."